Claims

1. An electronic photo-optical system for surveying, digitalizing and reproducing the external surface of a three-dimensional object, virtually or in plastic, composite or papery material, comprising an integrated module for calculating and managing informatics data, a scanner module and a reproduction module, characterized in that said integrated calculation module (VT-Data ^{II}) describes the mathematical logic utilized in the hardware in the scanner module (VT-MS ^{II}) and the reproduction module (VT-MF ^{II}) and carries out the operations of:

i) surveying, by means of a digital photo camera or a digital image survey and acquisition system, an image sequence of the object to be acquired associated with a consecutive and synchronized sequential projection, positioned and moved in predetermined steps, of a linear light beam projected parallel to the plane (**x,y**) on which the object is placed and striking the surface of the object to be surveyed;

ii) processing the information acquired as in i) above and reproducing the mathematics that describe the geometry of the external surface of the acquired object taken as model, generating the space coordinates of said object in accordance with a Cartesian reference system with three axes (**x,y,z**) as logic of the integrated calculation model (VT-Data ^{II});

iii) transferring the mathematical data acquired as in i) and ii) above to a PC for a virtual reproduction of the acquired object; rendering it available by means of specific software to the CAD 3D systems in order to be able to carry out modification interventions;

iv) transferring to a remote station the mathematical data acquired as in i), ii) and iii) above in order to reproduce there by means of reproduction module (VT-MF ^{II}) a copy in plastic, composite or papery material of the external surface of the object

acquired by the scanner module (VT-MS ^{II}) or the external surface of a PC-generated virtual object transferred by means of specific software from a CAD 3D file to a **3Dr, 3Drrt** and **3Dc**-type data file, in accordance with the logic indicated by the integrated calculation module (VT-Data ^{II});

v) colour printing the external surface of the object to be reproduced in plastic, composite or papery material by using the **3Dc**-type data file format, in accordance with the logic indicated by the integrated calculation module (VT-Data ^{II}).

2. An electronic photo-optical system in accordance with Claim 1, characterized in that the integrated informatics data calculation and management module (VT-Data ^{II}) generates, starting from information obtained from digital images, a numerical matrix **3Dr** representing the coordinates **(x,y,z)** of the external surface of an object to be calculated; a numerical matrix **3Dc** representing the colour coordinates of said object subjected to scanning; a second matrix set **3Drr, 3Drrt** obtained by a **3Dr** re-computation in accordance with a radial-type coordinate; the matrices computation being the result of the following passages:

- the data are acquired by using the rototranslation equations of the Cartesian reference system with axes **(x,y,z)** positioned at the centre **c** of the plane π and the second reference system **(X,Y,Z)** positioned at the centre **c1** of the plane π**1**; the directrix **Z** coinciding with the straight line through the points **c** of π and **c1** of π**1** and with the focal direction of the parallel-beam digital photo-electric apparatus employed for acquiring the images; the object to be scanned being placed on the plane π and the digital image survey device being situated on the plane π**1**, the planes π and π**1** being translated and inclined with respect to each other and the equation representing their relationship being **3D** such that:

$$\mathbf{3D = [P - T]*R}$$

- **R** = rotation matrix of the Cartesian system from the image base plane:

$$\mathbf{R} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\alpha - 90°) & \cos(\alpha) \\ 0 & \cos(\alpha - 180°) & \cos(\alpha - 90°) \end{bmatrix}$$

- **P** = vector of the coordinates identified on image plane $\pi 1$ with level **Z** associated with LED position = **(X,Y,Z)**;
- **X** = coordinate points of profile obtained from image;
- **Y** = coordinate points of profile obtained from image; ;
- $\mathbf{Z} = +\ \mathbf{z} * \sin(\alpha) - (\mathbf{Y} - \mathbf{z} * \cos(\alpha)) / \tan(\alpha) - (\mathbf{d}^2 + \mathbf{v}^2)^{1/2}$;
- **z** = level of the LED position associated with the image;
- **T** = vector of the translation coordinates of the Cartesian system of the image base plane: $\mathbf{T} = [0 - \mathbf{d}\ \ \mathbf{v}]$;
- **d** = horizontal measure of the distance between the centre **c** of the plane π and the projection of the centre **c1** of the plane $\pi 1$;
- **v** = vertical measure of the distance between the centre **c** of the plane π and the projection of the centre **c1** of the plane $\pi 1$;
- $\alpha = \arctan(\mathbf{v}/\mathbf{d})$;
- generation of the matrix set for the radial coordinate system: given the matrices **3Dr**, **3Dc,** let us consider their re-computation in accordance with a new coordinate system of the radial type. Having defined **3Dr** as a matrix of type **[x y z]** and the associated matrix **3Dc [x y C]**, which has a composition of the type **[x y z C]**, we can compute the transformation of the Cartesian coordinates from orthogonal to radial in accordance with the following definition:
- $\mathbf{Rg} = \mathbf{Rg0} + \mathbf{S}/360 * \theta$ = winding radium with respect to the axis of rotation

- **Rg** = $(x^2+y^2)^{1/2}$
- **Rg0** = initial radium of the axis of the spiral winding
- θ = **(Rg-Rg0)*360/S** = winding angle [in degrees]
- **S** = thickness of the spiral-wound sheet
- we now define the matrix describing the geometry of the object **obj** in the radial system as the matrix **3Drr** = **[Rg θ z]** associated with the corresponding matrix **3Dc** such as compose a space and surface-colour matrix of the type **[Rg θ z C]**; the matrix **3Drr** makes it possible to construct the volume of the object on the basis of a spiral-wound axis of rotation having a thickness **S**; the templates to be consecutive cut can be obtained, respectively, from the space confine edges of the matrix set that describes the volume of the object; given the matrix **3Drr,** the cutting condition **tg** is obtained in accordance with the following logic: given **3Drr** = **[Rg θ z]** ordered in accordance with increasing values θ, **z,** one defines the information:
- **tg** = active =1 (when $z_i \neq z_{i+1}$)
- **tg** = inactive = 0 (when $z_i = z_{i+1\ Drr}$)
- having composed all the information into the vector **[tg]**, one then composes the new matrix **3Drrt**:
- **3Drrt** = **3Drr** + **[tg]** = **[Rg θ z tg]**;
- thus, the object to be scanned, placed on the plane **π** in a first position defined as angle 0° with respect to the axis perpendicular to the plane **π** passing through its centre **c**, is struck by an LED light beam situated at a vertical level **z** with respect to the plane **π** and the digital photo-electric system of the parallel-beam type employed for the acquisition of the images, corresponding to the plane **π1**, sees the scanned object struck by the LED light beam with which there is associated the vertical level **z**; the digital photo-electric system surveys all the images of the object

in the angle 0° position at the various vertical levels comprised between **z**=0 and the height of the object by means of its subdivision into **n** parts, subsequently repeating the same operations for the rotations of the object into angular positions of 90°, 180°, 270° on the plane π with respect to the angle 0° of π**1**; the acquired images, translated into numerical matrices, having dimensions corresponding to the number of pixels utilized by the chosen format in the digital image acquisition system with numerical values corresponding to the real colour of the surveyed object, each acquired image being translated into a numerical matrix, while only the colour pixels struck by the LED beam are mathematically selected, converting these pixel positions into the numerical value 1 and associating the numerical value 0 with the remaining image pixels not struck by the beam, the matrices recomputed in this manner having dimensions corresponding to the number of image pixels, according to the horizontal and vertical directions, of which the positions of numerical value 1 correspond to the profiles associated with the vertical levels **z**, of these profiles there being furthermore considered a radial segment corresponding to -45°/+45° with respect to the reference angle (0°, 90°, 180° and 270°) and subsequently recomposed into 90° segments (-45°/+45°) until they describe a complete 360° profile; all this complete profile information, forming part of the plane π**1** with reference system (**X**,**Y**,**Z**) and associated with the **n** vertical levels, being translated into the reference system (**x**,**y**,**z**) by means of said rototranslation matrix, of which the final result represents the surface of the scanned object in Cartesian coordinates, i.e. the matrix **3D**, which is subsequently multiplied by the scale factor **Sf** that reporoportions all the information to the real scale of the acquired object, obtaining the numerical matrix **3Dr** = **3D** x **Sf**, the generation of the colour information being carried out by utilizing four images at rotation angles 0°, 90°, 180°, 270°, images acquired without the LED

beam projected, and subsequently recomposed into 90° segments by utilizing segments of -45°/+45° relative to the reference positions of the angles 0°, 90°, 180°, 270°, all the information assembled in this manner being translated into a numerical matrix **3Dc** in which the point represent the pixel position information and the corresponding colour number, which may be of the type of a 256-colour scale [0-255], or of the RGB type [0-255/0-255/0-255], the pixel positions of this matrix **3Dc** corresponding to the respective positions of the numerical coordinate matrix **3D**;

3. An electronic photo-optical system in accordance with Claims 1 and 2, characterized in that the integrated module for the mathematical calculation and management of the informatics data (VT-Data ^{II}) carries out the operations of:

- formulating (defining) the parameters for the acquisition of the information needed by the integrated calculation module (VT-Data ^{II}) for ordering the numerical matrices **3D**, **3Dr**, **3Dc**, i.e. formulating the resolution of the digital image survey system and the dimensional level parameter on the **z**-axis associated with the motion of the continuous or step-by-step type of a plane of the scanning light beam projected parallel to the base plane;
- acquiring the data relating to the external surface of a pre-existing object taken as model and subjected to scanning;
- mathematically processing the acquired data, translating them into Cartesian coordinates and generating a data file (numerical matrices **3D**, **3Dr**, **3Drr**, **3Drrt**, **3Dc**);
- managing the whole of the data by means of a dedicated software;
- managing the data by means of a hardware capable of acquiring and processing data at a high speed and a user interface software, the hardware may be integrated into the mother board of the modules VT-MS ^{II}, VT-MF ^{II} with specific VT ^{II} softwares;

- utilizing the numerical matrix **3Dr** for interfacing, by means of translation into CAD 3D format, with the three-dimensional formats of the CAD 3D systems;

- using the external geometry acquired object available to CAD 3D in order to make it possible for a rendering of the surface to be presented in a PC;

- importing data relating to the surfaces of objects from CAD 3D systems, translating them into the specific coordinate of the orthogonal and radial-type format system of the device (matrices **3Dr, 3Drr, 3Drrt** and **3Dc**);

- processing the data files by scaling the dimensions of the object either directly as desired and/or modifying them by means of the CAD 3D import-export system;

- utilizing the numerical matrices **3Dr, 3Drrt** and **3Dc**, obtained by acquisition or by import from CAD 3D, for the transmission of the data to the reproduction module VT-MF ^{II} either locally and/or by means of a network, wireless system and/or a direct telephone line to a remote station;

- by means of the specific coordinate format system: orthogonal type format and/or radial type format (refer to matrices **3Dr, 3Drrt** and **3Dc**), reproducing the volume of the object in plastic, composite and papery material and reproducing the corresponding colour with a fidelity of the digital photography type.

4. An electronic photo-optical system in accordance with Claims 1, 2 and 3, characterized in that the scanner module (VT-MS ^{II}) carries out the operations of:

- surveying and acquiring digital images or digital photogrammes/frames of any kind of object in predetermined angular positions; surveying and acquiring digital images or digital photogrammes/frames of the predetermined sequentially stepped positions of a plane of a LED-type light beam that is projected parallel to the base plane on which the object subjected to scanning is placed and strikes said object, associating with this predefined sequential projection active along the

image-shooting field of the employed digital system a synchronized motion such that this motion can be either continuous or made up of predetermined steps; in the case of continuous motion there is associated a video camera shot such as to obtain correspondence between photogrammes/frames and displacements in each unit of time, the photogrammes/frames and displacements coinciding with predefined and therefore known plane measures; when the motion is stepped, with each predefined position of the plane of the scanning beam there is associated the corresponding image obtained by the photo camera;

- providing, by means of digital acquisition, the data needed for the computation of the numerical matrices of the space coordinates **3Dr** and its corresponding colour matrix **3Dc** in accordance with said logic (VT-Data ^{II}).

5. An electronic photo-optical system in accordance with Claims 1, 2, 3 and 4, characterized in that the scanner module (VT-MS ^{II}) comprises:

- a digital photo camera or a digital surveying and image acqusition system placed such as to have image-shooting plane with a photographic system of the macro type, i.e. with parallel beams, and with the inclination of the shooting plane regulated in accordance with predefined angular position with respect to the framed rotating base plane;

- an LED system positioned on the vertical of the digital image-shooting device capable of generating a linear chromatic light beam projected parallel to the rotating base plane carrying the object to be scanned; the light beam is moved in coordination with stepped or continuous motion sequence of the employed digital image-shooting system, so that with each acquired image there is associated also the position with respect to the base plane of the projected light beam striking the object, i.e. the distance between the plane and the beam.

6. An electronic photo-optical system in accordance with Claims 1, 2, 3, 4 and 5, characterized in that the reproduction module (VT-MF ^{II}) carries out the operations of:

- reproducing and colouring in plastic, composite and papery material of the sheet-type, the external surface of a virtual object ordered by the orthogonal-type format numerical matrices **3Dr** and **3Dc** of the integrated calculation module (VT-Data ^{II}), as per Claims 1, 2 and 3;

- reproducing and colouring in plastic, composite and papery material of the roll-type, the external surface of a virtual object ordered by the radial-type format numerical matrices **3Drrt** and **3Dc** of the integrated calculation module (VT-Data ^{II});

- for the sheet-type support: sequentially cutting the profiles of the object to be reproduced in the **n** planes of which it is composed, corresponding materially to employed reproduction supports of a plastic, composite or papery type, said cutting operation being contained in the data of the matrix **3Dr**, because the **n** planes of level z_i of the volume of the object were utilized for generating this matrix; the hardware contained in the module system assures the decomposition of the matrix **3Dr** into the **n** planes, scaling the resolution as desired and the subdivision of the planes in accordance with the needs of the user, the cutting can be perpendicular or angular to the cutting base plane;

- for the roll-type support: continuos cutting the profiles of the object to be reproduced in the **n** spiral-wound planes of which it is composed, corresponding materially to employed reproduction supports of a plastic, composite or papery type, said cutting operation being contained in the data of the matrix **3Drrt**; the hardware contained in the module system assures the decomposition of the matrix **3Drr** into the **n** planes wound as a spiral around the axis rotation, and desired scaling resolution, the cutting can be perpendicular or angular to the cutting base plane.

7. An electronic photo-optical system (VT-MF ^{II}) in accordance with Claims 1, 2, 3, 4, 5 and 6, characterized in that it comprises:

- a space in which there are contained the trays in which the use material of sheet-type is stored;
- a space in which there is contained the axis/pin in which the use material of roll-type is stored;
- a system for loading, aligning and predisposing the chosen plastic, composite or papery support of sheet-type for the cutting phase;
- a system for loading, aligning and predisposing the chosen plastic, composite or papery support of roll-type for the cutting phase;
- a low-power laser cutting system brought into action in accordance with matrices **3Dr** and **3Drrt** logic;
- a colour-printing system dedicated to the chosen plastic, composite or papery support, brought into action in accordance with matrix **3Dc** logic using **3Dr** data for the sheet-type and **3Drr** data for the roll-type;
- a system for sensitizing the processed surface for the subsequent phase of specific adhesivation for the sheet-type support employed;
- a system for stacking and compacting the sheet-type supports processed as indicated above;
- a fax-type printing head in common use.

8. An electronic photo-optical system (VT-MF ^{II}) in accordance with Claims 1 to 7, characterized in that it carries out the following operations:

- loading the plastic, composite or papery sheet-type support from its feeder-tray onto the cutting base plane;

- loading the plastic, composite or papery roll-type support from its axis/pin onto the cutting base plane;

- cutting the $\mathbf{n}^{th}$ plane profile into which the object has been subdivided in accordance with matrix **3Dr** logic, and separation of the positive outline-template thus obtained from the corresponding negative counter-template for sheet-type support;

- cutting the $\mathbf{n}^{th}$ spiral-wound profile into which the object has been subdivided in accordance with matrix **3Drrt** logic for roll-type support;

- colour-printing by means of an inkjet system or a system compatible with the employed plastic, composite or papery supports in accordance with matrix **3Dc** matrix according with **3Dr** logic for the sheet-type supports and according with **3Drr** logic for the roll-type supports;

- sensitisation and activation of the processed of the sheet-type support for adhesivation in accordance with the specific characteristics of the employed plastic, composdite or papery material;

- positioning of the shaped sheet-type support on the specific stacking tray for receiving the subsequent supports processed as indicated above;

- compaction of the sheet-type supports processed as indicated above, effected by means of consecutive adhesivation of the step-by-step type and with fixing and assembly of the final supports in accordance with the specific characteristics of the employed material;

- three-dimensional in-the-round configuration of the acquired object by means of specific jointing of the sheet-type and the roll-type supports processed as indicated above, coupling the coloured sections of the volume of the object by means of coupling pins inserted in the corresponding cavities generated in accordance the enounced logic, this combinatorial property making it possible to manage in an unlimited manner the

dimensional size of the object to be reproduced by means of the re-proportioning, the decomposition and the reconfiguration into an arbitrary number of coloured sections of the object or the objects to be reproduced, previously processed in accordance with the logic indicated by VT-Data [II].

9. An electronic photo-optical system in accordance with Claims 1 to 8, wherein the sheet-type and the roll-type supports that reproduce and realize outlines of objects subjected to scanning or obtained from a CAD 3D design (system) are characterized in that they are made of plastic, composite or papery material, are standardized as regards form, perimeter and separation inserts suitable for separating the guide edge of the processed outline template in accordance with said logic and are dedicated and specific in accordance with the typology of the employed material; each sheet-type and roll-type supports having specific characteristics that pair them with the corresponding colouring material, the shaping ordered in accordance with matrices **3Dr** and **3Drrt,** logic also assuring the cutting of particular cavities at the base of some sections of the object to be reconfigured, incisions that generate the pin spaces or cavities utilized for uniting the processed parts of the object by means of specific insertion and coupling pins having outlines equal to the cut cavities, the position and the number of the pins needed for a coupling being a function of the dimensions of the object to be reproduced, and the colouring of the sheet-type and roll-type supports being carried out in accordance with the colour information received from the matrix **3Dc**, in which each matrices **3Dr** and **3Drr** have associated with it the colouration of the desired object that reproduces the chromaticity with reproduction of the digital photography type of the object in accordance with the image acquired or defined by the user by means of information transferred from a CAD 3D system.